

Soil Fungi Critical to Organic Success

One casualty of America's agricultural revolution were valuable native soil fungi that enabled crops to grow well with less water, nutrients, and pesticides.

Increased agricultural productivity has been largely dependent on high levels of chemical fertilizers and synthetic pesticides. There is a growing interest in reducing this dependency by encouraging biologically based systems to enhance productivity and product quality on farms.

That's exactly what ARS chemist Philip E. Pfeffer and his co-workers hope to accomplish by helping farmers reestablish the beneficial soil organisms called mycorrhizal fungi. Pfeffer is at the Agricultural Research Service's Eastern Regional Research Center (ERRC) in Wyndmoor, Pennsylvania.

Mycorrhizal fungi live within the roots of most plants in a mutually beneficial relationship (symbiosis). They help roots scavenge more nutrients and water from the soil in exchange for sugar to make the molecules they need to live and grow. These fungi extend long threads, called hyphae, outside the

Micrograph of fungal arbuscules (treelike structures) in the cells of leek roots.

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Fields may eventually have colonies of beneficial microbes rivaling those of yesteryear.

PEGGY GREB (K9434-1)



At Stoneleigh Estate in Villanova, Pennsylvania, chemist Philip Pfeffer (left) and microbiologist David Douds inspect a tropical grass planted to produce compost-based inoculum.

roots. The hyphae transport phosphorus and other nutrients into plant roots. Mycorrhizae also enable plants to use water more efficiently and resist pests.

Pfeffer and co-workers study the most common type of mycorrhizae, which are called endomycorrhizae because the fungi live inside—rather than between—root cells. They are also called arbuscular mycorrhizae because of the treelike structures (see photo above), or arbuscules, they build within the cells. The branches transfer nutrients to the plant cells in exchange for sugar for the fungi. The trunks of the arbuscules attach to the hyphae.

Today, farmers who grow row crops, like corn and soybeans, must rely on whatever soil fungi survived the decades of high chemical application that began when American agricultural production intensified in the 1950s.

Horticultural crop producers fare better because they can buy potting mixes with beneficial fungi added. Home gardeners can buy the fungi as soil inoculants from seed catalogs. But it's impractical for farmers to buy and apply the large quantities of fungi they'd need for farm fields.

On-Farm Fungi Production

One member of the ARS team, David D. Douds, is supervising experiments to find practical ways for farmers to grow and apply their own mycorrhizal fungi. At the Rodale Institute Experimental Farm in Kutztown, Pennsylvania—a long-time proponent of organic farming—and at nearby Stoneleigh Estate, Douds has tried growing the fungi in compost. That would enable farmers to apply the fungi along

with compost with no extra effort or cost.

Douds planted a tropical grass in the compost after inoculating its roots with arbuscular mycorrhizal fungi. He hoped the roots would harbor the fungi and spread them throughout the compost, but the fungi didn't spread well enough.

"We think the compost was so rich in nutrients that the grass roots didn't encourage the fungi to proliferate, because their help wasn't needed for getting nutrients," he says. This spring, Douds and his colleagues will try mixing the compost with a less nutrient-rich soil to see if that promotes fungal proliferation.

The researchers' goal is to have suppliers sell farmers colonized host plants for planting—not as a crop, but to start colonies of the fungi in soil, compost, or a compost/soil mix. Then, after the fungi have had time to multiply, farmers would apply the colonized soil in manure spreaders along with their compost.

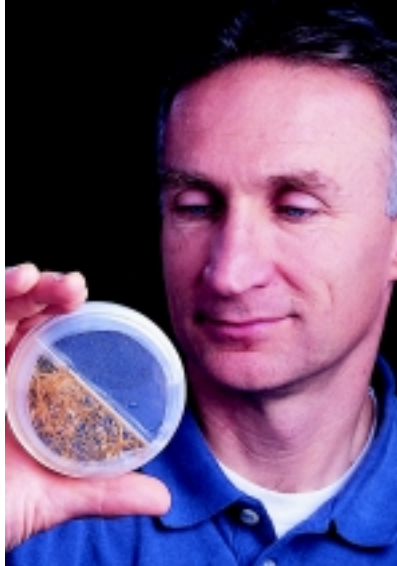
"Instead of farmers having to buy and transport a whole field's worth of inoculum, they could buy a small fraction packed in with host seedlings. Then, they'd plant the mycorrhizal seedlings and increase the inoculum on their own," Douds explains. Farmers would eventually have crop fields with colonies of beneficial microbes rivaling those of yesterday.

How Host Roots Communicate With Mycorrhizal Fungi

Another member of the ARS team, chemist Gerald Nagahashi, has found that plant roots release signals to encourage or discourage proliferation during at least two of the fungi's seven life stages. He found that in the first stage, when the fungal spores start growing hyphae in the soil, roots exude compounds that encourage prolific hyphal growth. This helps the fungus find the root, colonize it, and produce the arbuscules.

"We used carrot roots for these studies because they're a good model and can be grown easily in liquid culture," Nagahashi says. The scientists have improved techniques for growing the fungi with carrot roots in petri dishes and hope to do this someday without the roots.

Nagahashi also did an experiment using light and found it triggered more fungal



Microbiologist David Douds inspects carrot root culture system used to study *in vitro* interactions of the host plant and mycorrhizal fungi.

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Chemist Gerald Nagahashi transfers carrot roots into liquid medium. Compounds released into the medium by these roots will be used for *in vitro* studies.

hyphal branching. "We predicted that exposing inoculum to light would increase colonization of corn seedlings by the fungi, and that's exactly what happened," he says.

The team is studying the basic physiology of the mycorrhizal fungi and their interactions with plants so they can find a way to grow fungal colonies without host plants. This would permit large-scale production of inoculum for field application.

"We also need to find out what nutrients and other conditions have to be met so the fungi grow through all seven life stages and multiply," Pfeffer says. "Using specially marked molecules and nuclear magnetic resonance spectroscopy to analyze a mycorrhizal system in a petri dish, we've learned a great deal about how carbon—in the form of carbohydrates—flows from the

plant to the fungi. We've also learned that at certain stages of the life cycle—such as during spore germination—the fungi can take carbon directly from the soil without getting it from plants, which encourages us.

"However, we need to find out why the spores are unable to utilize this carbon to replenish their lipid stores, which are needed for completion of their life cycle," says Pfeffer. "We'd like to be able to feed the fungi glucose in the laboratory and have them reproduce in mass quantities in fermentation vats, as we do with bacteria and other fungi."

In collaboration with Yair Shachar-Hill and Peter Lammers at New Mexico State University, the ERRC team is also examining gene expression of these fungi at each life-cycle stage. With this information the researchers hope to turn on the mechanisms necessary for the fungi to complete their life cycle in the absence of the host plant.—By **Don Comis, ARS.**

This research is part of Soil Resource Management (#202) and Plant Biological and Molecular Processes (#302), two ARS National Programs described on the World Wide Web at <http://www.nps.ars.usda.gov>.

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